COMPARISON OF SHADE SELECTION BY SMARTPHONE CAMERA AND DSLR CAMERA USING VITA 3D MASTER SHADE GUIDE- AN INVITRO STUDY

A Dissertation submitted

in partial fulfillment of the requirements

for the degree of

MASTER OF DENTAL SURGERY

BRANCH –I

PROSTHODONTICS

THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY

CHENNAI- 600032

2016-2019

ADHIPARASAKTHI DENTAL COLLEGE & HOSPITAL

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CERTIFICATE

This is to certify that **Dr. VIDHU ANTONY**, Post Graduate student (2016-2019) from the Department of Prosthodontics, Adhiparasakthi Dental College and Hospital, Melmaruvathur – 603319, has done this dissertation titled "**COMPARISON OF SHADE SELECTION BY SMARTPHONE CAMERA AND DSLR CAMERA USING VITA 3D MASTER SHADE GUIDE- AN INVITRO STUDY**" under our direct guidance and supervision in partial fulfillment of the regulations laid down by the Tamilnadu Dr. M.G.R Medical University, Chennai – 600032 for MDS., (Branch-I) Department of Prosthodontics Degree Examination.

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ACKNOWLEDGEMENT

I thank **ALMIGHTY GOD** for all his blessings and for being with me throughout and leading me to prepare and complete this dissertation. I thank our Correspondent **Dr. T. Ramesh**, **MD.** for his vital encouragement and support.

I am thankful to **Dr. Thillainayagam MDS.,** our beloved principal, Adhiparasakthi Dental College and Hospital, Melmaruvathur for providing me with the opportunity to utilize the facilities of the college.

I avail this opportunity to express my gratitude and reverence to my beloved teacher **Dr. N. VENKATESAN. MDS**. , Professor and Head, Department of Prosthodontics, Adhiparasakthi Dental College and Hospital, Melmaruvathur. His pursuit for perfection and immense support were a source of constant inspiration to me and without which such an endeavour would never had materialized.

I am extremely thankful to my guide **Dr.K. PRABHU, MDS.** Words cannot express my gratitude for his confidence in my ability to perform this study.

It is my duty to express my thanks to my teacher **Dr. A.S. RAMESH, MDS** for his favour rendered for my study**.**

I am thankful and express my gratitude to my teachers **Dr.SAKSHI MADHOK,MDS.,** Reader**,** and senior lecturers **Dr. A. KIRUBAKARAN**, **Dr. MOHAMMED IMTHIYAS, Dr.V.C. KARTHIK, Dr.I.RAMESH KAARTHIK,** for there valuable suggestions and encouragement throughout the completion of my Main dissertation.

I also wish to thank my seniors, and my post graduate colleagues **Dr.GANAGAMANI, Dr.NITHYAPRIYA** and I warmly acknowledge my juniors **Dr.JEEVITHA, Dr.KABILAN, Dr.MITHRA, Dr. PRAVIN, Dr. PAZHANI** and **Dr. MUTHU ANNAMALAI** for their help and support.

I thank **Mr. Maveeran**, **B.com.,MLIS.,** Librarian and the library staff **Mr.K.Selva Kumar**,**B.A.,** Adhiparasakthi Dental College and Hospital, Melmaruvathur, for favours rendered.

I owe my gratitude to my Parents **Mr.A.D.ANTONY**, and **Mrs.SUKRUTHA ANTONY,** who stood beside me during my hard time and sacrificed so much to make me what I am today.

I thank my loving husband **Mr. ARUN LEO,** who has been a constant source of support and encouragement during the challenges of graduate life.

I would also like to offer my heartfelt thanks to my brother **Mr.VIVIAN ANTONY,** sister in law **Mrs.PONNY LEE,** In Laws **Mr. UVARAJ** and **Mrs.(Dr.) THRESIKA UVARAJ** for their constant encouragement throughout my career.

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I hereby declare that no part of the dissertation will be utilized for gaining financial assistance or any promotion without obtaining prior permission of the Principal, Adhiparasakthi Dental college and Hospital, Melmaruvathur -603319. In addition, I declare that no part of this work will be published either in print or in electronic media without my guide's knowledge who have been actively involved in dissertation. The author has the right to reserve for publish work solely with the permission of the principal, Adhiparasakthi Dental college and Hospital, Melmaruvathur-603319.

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ABSTRACT

BACKGROUND

The success of anterior restoration primarily depends on proper shade selection when compared to the natural dentition. Precise shade determination is dependent on clinical skill, shade guide system and lighting conditions. With technological improvement in communication networks, internet and electronic gadgets among the contemporary society, a subsequent translation has been developed in the field of dentistry too. Since a decade DSLR cameras have been used in dentistry and has proven to be at par with various other instrumental methods for shade selection. However there have been rapid increase of smartphone cameras for shade matching and ease of communication with the dental laboratory. Little is known about the quality of the image taken using smartphone camera.

AIM

The purpose of the study is to compare the L, a and b values of DSLR Camera and smartphone camera with that of the vita 3D Master shade guide and also to evaluate the effectiveness of smartphone camera to that of the DSLR Camera.

METHOD

A commercial shade guide (3D master vita shade guide, germany) was employed in this study. The images of the individual shade tabs were captured using Samsung S9 plus smartphone camera and DSLR canon EOS 1200D.

A total of 104 image was taken i.e, 2 photos for each of the 26 shade tabs were taken both in smartphone camera and DSLR camera. Best Image was selected depending on the clarity and sharpness. These images were taken on a bright daylight (temperature 4000-5000k). There was a fixed distance of 17cm between the shade tab and the camera and the shade tab was placed in front of a grey card.

The L,a,b values of the raw images of smartphone were obtained using color lab and that of DSLR camera was obtained using adobe photoshop. The delta E Values of smartphone and DSLR in comparison with that of the manufacturers shade tab values were noted using color lab CIE2000 software.

RESULTS

Wilcoxon signed rank test is performed between DSLR and Smartphone photographs and a statistically significant difference are found between the amount of deviation of L,a and b values in DSLR and Smartphone photographs.

CONCLUSION

Within the limitation of this study 73% accuracy is obtained for DSLR shade tabs whereas only 50% accuracy is obtained for smartphones images.

KEYWORDS

Shade selection, DSLR Camera, smartphone camera, vita 3D Master shade guide.

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SP	SMARTPHONE
Λ	DELTA

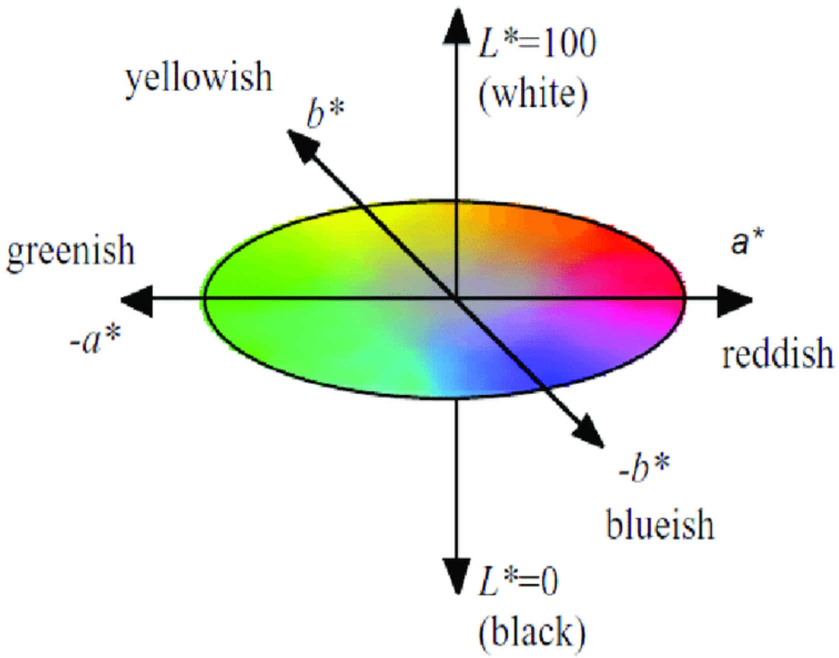
Accurate Shade matching is a challenging aspect of aesthetic dentistry. The color of an object is a characteristic given by the light that comes from the object to the human eye and is dependent on the light wavelength and the subjective experience – visual perception of colors is a physiological phenomenon based on the visual system.

Traditionally, shade matching of teeth in dentistry is done by visually comparing the color of tooth/teeth with standard shade guide tabs, the operator choosing that which he/she deems to be the best or closest match.[1] These shade guides offer relatively quick and cost-effective methods of shade matching, offset by the major problems of the subjective variability of shade matching, the polychromatic nature of teeth, and the limitations of dental shade guides that incompletely represent the colour range of natural teeth.[2] Since color perception varies not only among individuals but for the same individual over time, several methods were recently used to assess tooth color which includes spectrophotometer, colorimeter, spectroradiometer, image analysis techniques etc.

There are different color systems available like greyscale, RGB, CMYK, lab etc. The oldest color system which was created by Albert H.Munsell in 1905 attributed Hue, value or lightness and chroma.

CIELAB is a color space specified by the International Commission on Illumination which describes all the colors visible to human eye and was created to serve as a device-independent model to be used as a reference. The three coordinates of CIELAB represents the lightness of the color(L= 0 yields black and L=100 indicates diffuse white), its position between red and green ("a" negative value indicates green and positive value indicates red) and its position between yellow and blue ("b*" negative value indicate blue and positive value indicate yellow) The measure of change in visual perception of two given colours is denoted by ΔE - (*Delta E*, *dE*). It is a metric for understanding how the human eye perceives colour difference.

FIGURE 1.



Clark in 1931 introduced a custom shade guide which was based on visual assessment of human teeth, and was recorded in Munsell's system of Hue, value and chroma. Since the available shade guides had few deficiencies, Sproull in early 70's suggested that an ideal shade tabs should be well distributed and logically arranged in color space preferably based on Munsell color system. As per Miller, the thickness of shade guide should not be more than the average porcelain veneer and the material should also be same as that of the restoration. The limitations of shade guides are factors that compromise shade-matching procedures in dentistry and contribute to the dissatisfaction of clinicians, technicians and patients.[3] To overcome these deficiencies new generation shade guides were developed like Vita 3D master shade guide which features a systematic distribution of shade tabs within the color space and Shofu offered the natural color concept.

The usage of digital cameras have been widely adopted in recent years in the field of dentistry. During communication with technicians, dentists can present not only the dental morphology and colors, but also the surface texture, color distribution and other information under the intra-oral conditions. Intra-oral images with the reference shade tabs correctly positioned next to the teeth are also useful in shade matching. Shade matching using the digital images can minimise the gap of color communication between dentists and technicians.

In this modern era of technology Smartphones cameras are replacing DSLR camera and have become prevalent devices. Improving hardware and faster wireless standards have bolstered the growth of the smartphone industry. With every new launch of smartphones the camera specifications have also improved to a level which is at par with the DSLR Cameras. Their clinical applications for healthcare professionals have increased. Reason behind the increased use of smartphones include better portability, less bulky, less noticeable and more convenient, their self-contained CPU computing capability, enriched functionalities, various software applications, wireless connectivity, and high-resolution photographic technology. Dedicated photographs captured by smartphones may be used as color references in dental shade matching. Because color communication requires photographs with reference shade tabs, smartphones can increase the ease of wireless communication between dentists and the laboratory technicians who fabricate dental prostheses.

The aim of the study is to compare the L,a,b values of image taken in smartphone and DSLR camera with that of the vita 3D shade tabs and create a standard for smartphone photography for shade selection.

The purpose of the study is to

a) Compare the L,a and b values of DSLR Camera with that of the Vita 3D Master shade guide.
b) Compare the L,a and b values of smartphone camera with that of the vita 3D Master shade guide.
c) Assess the effectiveness of smartphone camera in shade selection

Shade matching of natural teeth with artificial restoration is one of the most challenging aspect of prosthetic dentistry. Color of natural teeth will vary in color and shape. These variations of tooth shows different background and personality of the patient. Whether we are restoring one tooth or many, the ability to assess and properly communicate information to our laboratory can be greatly improved by learning the language of color and light characteristics.[4]

In visual color matching Tooth shade guides offer a series of standards simulating the natural teeth, and the dentist must decide which standard offers the most acceptable color match with the tooth or teeth in question and if such a match will please the patient.[5]

Kuehni claim that in normal color perception 2 million colors can be distinguished when seen on a grey background [6] and, using logical reasoning and experiments, he has demonstrated that a realistic value for the number of stimuli that can trigger color perceptions is around 40 million [7]. The receptors located in the central area of the retina, cone cells, are responsible for daytime viewing and for the identification and differentiation of colors [8]. Color perception is a chain process that involves the cone cells that are divided into 3 types of cells that react to three different wavelengths corresponding to red, green and blue. Rod cells are responsible for interpreting differences of lightness (value) and cone cells are responsible for interpreting the base color and its saturation (hue and chroma).

Saleski [9] proposed that an ideal light source for shade matching should have the following qualities:

(i) it should have complete colour content,

(ii) it should have enough intensity to overcome the influence of ambient room light and should show slight as well as dominant pigmentation in the tooth,

(iii) it should be comfortable to the eye to perceive colour accurately and comfortably,

(iv) the light should be standard and should be unchanging in quality and quantity from day to night or season to season.

Several uncontrolled factors such as fatigue, aging, emotion, lighting conditions and metamerism can also affect color perception.

In the context of planning and performing dental treatments, esthetics in general represents an important outcome from patient's perspective, regardless of age [10]. From this perspective the correct determination of tooth color can be considered crucial. Generally, in the absence of any visual impairment the color determination improves over time[11] through training and exercise.[12,13]

Thus the observers must be trained for color discrimination by repeated use of standard tests as the ability to distinguish colors may not be uniform among observers.

M D RUSSELL et al (2000) [14] conducted a study and observed that teeth become lighter when they are dried. The present study was designed to quantify these changes and time taken for tooth color to return to normal. The color of an upper central incisor in each of seven subjects were measured using reflectance spectrophotometer before and after application of a rubber dam and , in another seven subjects before and after taking a polyvinylsiloxane impression. There were statistically significant changes in the L, a and b values following rubber dam application and in L value following impression taking. The results demonstrate that the teeth become brighter and less color saturated after rubber dam application and brighter after impression taking. The original values were regained after 30 mins.

James C et al (2000) [15] conducted a study to evaluate the CIELAB, CMC (2:1), and CMC (1:1) formulas to identify which provides the best indicator for acceptability of small color differences in the esthetic dental restorative materials, to determine if different groups of observers have different levels of acceptability, and to estimate the color difference that would indicate acceptability between a restoration and an adjacent tooth. The subject population of human observers was divided into four groups, each containing 12 subjects. The composition of the groups were: Group 1, dental auxiliaries and hygienists;

Group 2, dentists; Group 3, dental materials scientists; and Group 4, patients. A color vision screening test was administered to each subject to ensure that only observers with normal color vision were evaluated. y. This test was composed of six sets of discs fabricated from dental composite resin restorative materials. Each set consisted of one standard disc representing tooth color. Color differences between the standard discs and the restoration discs were calculated in CIELAB, CMC (1:1), and CMC (2:1) color units. In regard to the acceptance or rejection of dental restorations based only on color difference, the CMC (1:1) color difference formula gives better correlation than the CIELAB formula for small color differences in the esthetic dental restorative materials. There were significant differences found between the experiment groups in regard to acceptability of color differences using the CMC (1:1) and CIELAB formulas. By rejecting smaller color differences, the dental auxiliaries group proved to be more discriminating in accepting differences between tooth and composite resin restorative material color than were patients. The mean 50:50 DE replacement points for all observers were 2.29 and 2.72 color units for the CMC (,:c) and CIELAB formulas, respectively.

RD Paravina et al (2002) [16] conducted a study to analyze color parameters and color compatibility of two randomly chosen Vita shade guides, as well as to propose possible clinical guidelines.

In this study the data were recorded using a colorimeter set to standard illuminant source C and the CIE Lab system. A custom adapter system, which allowed a measuring area at the middle third of the tabs, was produced. Each of 42 tabs was recorded one time each on three different days. Color distribution was examined in diagrams whose coordinates were L a b and L C H color coordinate pairs. Color difference ranges of Vitapan Classical and Vitapan 3D Master were 14.3 and 19.2, respectively. It was concluded that Compared to Vitapan Classical, chromaticity ranges of Vitapan 3D Master were extended in the desired directions: hue was extended toward yellow-red, and saturation was extended toward more saturated tabs. Compared to Vitapan Classical, Vitapan 3D Master tabs were more uniformly spaced. The examined shade guides were found to be color compatible

Stephen Phelan (2002) [17], presents a single onlay case that was significantly enhanced through a detailed communication process between the clinician and the laboratory technician. By using colour slides as part of the dentist–technician communication process, the author found that the technician was better able to create an esthetic, accurate and successful restoration that addressed the patient’s needs.

Alma dozic et al (2003) [18] conducted a study to determine, quantitatively, the effect of different thickness ratios of opaque porcelain (OP) and translucent porcelain (TP) layers on the overall shade of all-ceramic specimens. The CIELAB values of 5 assembled specimens, each consisting of 2 or 3 discs (CORE 0.70 mm/OP - 0, 0.25, 0.50, 0.75, or 1.00 mm/TP 1.00, 0.75, 0.50, 0.25, or 0 mm) were determined with a spectrophotometer for the Vita shades A1, A2, and A3. Distilled water was used to attain optical contact between the layers. Black or white backgrounds were used to assess the influence of the background on the final shade. Color differences (ΔE) between layered specimens were determined. Correlation between the thickness ratio and the L, a, and b values was calculated by 2-tailed Spearman correlation analysis. Results indicated that Redness a and yellowness b increased with the thickness of OP for all shades. Redness a ($P < .01$ for all shades) correlated more strongly with thickness than yellowness b ($P < .01$ for A1 and A3; $P < .05$ for A2). The lightness (L) was shade dependent. The correlation (r) between OP/TP thickness and L was 0.975 ($P < .01$) for shade A1, 0.700 (not statistically significant) for shade A2, and 0.900 ($P < .05$) for shade A3. Thus it was concluded that Small changes in thickness and shade of opaque and translucent porcelain layers can influence the final shade of the layered porcelain specimen.

F.D. Jarad et al(2005) [19] conducted a study to develop a shade matching method based on digital imaging and to compare observers' ability using this method with the conventional one set against a spectrophotometric 'gold standard'. Two Vita Lumin shade guides were used in this study, nine shades being selected from the first Vita Lumin shade guide, and the second shade guide was used to match the selected shades. A Nikon Coolpix 990 digital camera with Nikon SB21B ring flash was used to record the digital images of the shade tabs of the two shade guides and the images were processed using Adobe Photoshop software. A total of 27 samples were matched with a digital shade guide prepared from the digital images of the second shade guide by 10 observers on a computer screen. The observer's shade matching performance was significantly better with the computer method compared with the conventional one. There was a large variation in the observer's matching ability. The digital camera can be used as a means of colour measurements in the dental clinic.

Alvin G Wee et al (2006) [20] studied the accuracy of commercial digital camera for dental applications. They used three types of camera Nikon D100, Canon D60 and Sigma SD9 camera. Pictures were in raw format and they converted it into "TIFF" via the converting software which evaluated the CIELAB values obtained and compared with the calibration models. The authors concluded that these cameras when combined with the appropriate calibration protocols shows potential for use in the color replication process of clinical dentisty.

Funda Bayindir et al (2007) [21] did a study to determine and to compare the coverage errors (CEs) of 3 different shades in a selected population. The coverage errors of the following shade guide systems were evaluated to determine which shade guide system is most effective in producing the best visual shade match: (1) Vita Lumin, (2) Chromascop, (3) Vitapan 3D Master, and (4) a combination of the 3 shade guide systems. The spectral reflectance values of the central one ninth (1-mm diameter) of each shade tab (without a backing) were measured with a spectroradiometer and an external light source at wavelengths from 380 nm to 780 nm at 2-nm intervals. The color values of 359 anterior teeth were measured with the same protocol. The Vitapan 3D Master shade guide system resulted in the lowest coverage errors compared to the Vita Lumin or Chromascop shade guide systems. Coverage errors for the Vitapan 3D Master shade guide system did not differ significantly from the coverage errors when all 3 shade guide systems were combined.

Lars Schropp et al (2009) [22]did a study to evaluate the efficacy of digital photographs and graphic computer software for color matching compared to conventional visual matching and stated that Shade matching assisted by digital photographs and computer software was significantly more reliable than by conventional visual methods.

Jee-ha Choi et al (2010) [23] did a comparative study of visual and instrumental analyses of shade selection and concluded that the Overall, instrumental analysis is more accurate and reproducible than a visual assessment, making the difference clinically acceptable.

Alpar Caglar & Kivanc Yamanel (2010) [24] did a study to evaluate the color parameters of composite and ceramic shade guides which were determined using a colorimeter and digital imaging with illuminants at different color temperatures. Two different resin composite shade guides, namely Charisma (Heraeus Kulzer, Hanau, Germany) and Premise (Kerr Corporation, Orange, CA, USA), and two different ceramic shade guides, Vita Lumin Vacuum (VITA Zahnfabrik, Bad Säckingen, Germany) and Noritake (Noritake Co., Nagoya, Japan), were evaluated at three different colour temperatures (2,700 K, 2,700–6,500 K, and 6,500 K). This study concluded that digital imaging method could be an alternative for the colorimeters unless the proper object-camera distance, digital settings and suitable illumination conditions should be supplied.

Won-Suk Oh et al (2010) [25] did a study to determine the validity of the digital photocolorimetric (PCM) method in matching the color of human teeth. First, two Vitapan Classical shade guides, each containing 16 shade guide teeth, were visually shade matched, and digital photographs of each three pair of shade guide teeth were taken in a color matching booth. Secondly, visual shade matching of the upper central incisors of 48 subjects was performed by two prosthodontists independently in a chair, using the Vitapan Classical shade guide. The three closest shade guide teeth were visually selected and ranked in order of preference, for which digital photographs were taken under ceiling daylight-corrected fluorescent lighting. All digital images were analyzed on a computer screen using software to calculate the color difference between the reference tooth and other teeth in the same digital image. The percent color matching for the shade guide teeth and human teeth was 88% and 75%, respectively. There was no statistically significant difference in matching the tooth color between the shade guide teeth and human teeth. The digital PCM method is valid for the range of human teeth based on the Vitapan Classical shade guide. This method enhances communication with the laboratory personnel in matching the tooth color

Oi Hong Tung et al (2011) [26] conducted a study and hypothesized that different illuminants and camera's white balance setups shall influence color rendering of digital images and affect the effectiveness of color matching using digital images. Fifteen ceramic disks of different shades were fabricated and photographed with a digital camera in both automatic white balance (AWB) and custom white balance (CWB) under either light-emitting diode (LED) or electronic ring flash. The Commission Internationale d'Éclairage *L a b* parameters of the captured images were derived from Photoshop software and served as digital shade guides. They found a significantly high correlation coefficient (r^2 > 0.96) between the respective spectrophotometer standards and those shade guides generated in CWB setups. It was concluded that the reliability of color matches with digital images is much influenced by the illuminants and cameras white balance setups, while digital shade guides derived under LED illuminants with CWB demonstrate applicable potential in the fields of color assessment.

Fabiana Takatsui et al (2012)[27] did a study to analyze the color alterations performed by the CIE L a b system in the digital imaging of shade guide tabs, which were obtained photographically according to the automatic and manual modes. Four Vita Lumin Vaccum shade guide tabs were used: A3.5, B1, B3 and C4. An EOS Canon digital camera was used to record the digital images of the shade tabs, and the images were processed using Adobe Photoshop software. A total of 80 observations were obtained, leading to color values of L, a and b. The color difference (ΔE) between the modes were calculated and classified as either clinically acceptable or unacceptable. It was concluded that the B1, B3 and C4 shade tabs can be used at any of the modes in digital camera (manual or automatic), which was a different finding from that observed for the A3.5 shade tab which demonstrated a clinically unacceptable shade.

W K Tam et al (2012)[28] conducted a study in which they proposed to compare the color of shade tabs taken by a digital camera using appropriate color features. Vita 3D master shade guide and Canon EOS 1100D digital camera were employed. Shade tab images were compared in two reference strategies. The color of tooth surface was presented by a content manually cropped out of the image. The content was divided into 10*2 blocks to encode the color distribution. Color features from commonly used color spaces were evaluated. The top n matches were selected when the least n shade distances between the shade tabs were attained. Using $Sa*b*$ features, the top one accuracy was 0.87, where the feature S is defined in HSV color space, $a*$ and $b*$ features are defined in $L\ a\ b$ color space. $Sa*b*$ were suitable features for shade matching using a digital camera~~s~~ in this study. Both the color and texture of the tooth surface could be presented by the proposed content-based descriptor. Clinical use of digital cameras in shade matching became possible.

Mehta R et al (2014) [29] reviewed on Shade selection-Blending of conventional and digital methods and inferred that the use of technology with different devices in shade selection may eliminate subjectivity of choosing and the use of photography to communicate shades and characterizations.

Karl glockner et al (2015) [30] conducted a study to analyse the reliability of an Easy Shade device in shade selection compared to visual shade-matching method. This study was based on the examination of five hundred patients of Dental Clinic Graz Austria. The shade matching was observed in right central maxillary incisor (11), right second maxillary incisor (12) and right maxillary caninus (13). The data obtained for both experimental groups were analyzed using the ANOVA test. The level of significance was set at 5%. Based on their clinical findings they concluded that: both, the visual and digital tested methods were similar accurate in the shade determination. Both methods in combination provide a good performance in determining the colour of tooth.

Raluca Draghici et al (2015) [13] conducted a study to analyze the ability of dental students to visually assess tooth color, by the usage of Vita 3D Master shade guide, by comparing their matching to results of an instrumental method i.e., Vita EasyShade. Students showed at a group level relative good ability of visually determining the color of the teeth, by the usage of 3D Master shade guide.

Nakhaei M et al (2016)[31] conducted a study to evaluate the influence of shade guide type and professional experience on shade-matching results and concluded that the type of dental shade guide affected the shade-matching results i.e. when compared with Vitapan Classical shade guide, use of the Vitapan 3D-Master shade guide improves shade-matching results, also the level of experience was not found to be an influential factor in shade matching when 3D-Master shade guide was used.

Dhruv Anand et al (sep 2016) [32] did a study to ascertain if digitally acquired images with an SLR camera can be used as an alternative to the VITA easyshade spectrophotometer for obtaining the shade of the teeth. They concluded that an SLR camera with Adobe photoshop CS5.1 as an adjunct can be used as an alternative to spectrophotometer in obtaining 'l' and 'b' values accurately.

Vivek Pandey et al (june 2016) [33] conducted a study to determine validity of combination of digital photography and conventional method of shade selection using shade guide for accuracy in matching colour of human tooth over only conventional method of shade selection. They concluded that whenever possible, use both, as they complement each other and can lead towards predictable esthetic outcome. Thus within the limitations of this study, tooth color matching using the digital photography method was found to be valid with the use of the Vitapan Classical shade guide. This digital technology could provide an alternative accurate as well as cost effective method of tooth color matching by enhancing communication with the laboratory personnel.

Ramin Negahdari et al in 2016 [34] did a comparative study between Vitapan classical and 3D master shade guide systems and the conclusion was that the repeatability percentages of shade matching in 3D Master system was high

Weng-kong Tam in june 2017 [35] conducted a study in which they proposed using support vector machines (SVM), which are outstanding classifiers, in shade classification. They concluded that smartphone cameras, even those without internal setting features, can be used as shade measuring instruments when an appropriate computational method is employed. The findings reveal that the proposed SVM classification might outperform the shade-matching results of previous studies that have performed similar measurements of Delta E levels or used an S, a*, b* feature set.

Hossein Dashti et al (2017) [36] stated that the process of disinfection and sterilization may change the color of shade tabs and ultimately affect shade-match procedure. The shade tabs that were autoclaved showed much greater color change than those that were disinfected

Juzer S. Miyajiwala et al (2017)[37] did a comparative study on 3 different methods used for shade selection, i.e., visual method, spectrophotometer, and digital photography method and came to a conclusion that the digital photography method emerged as reliable method for shade selection in a clinical setup.

MATERIALS- Smartphone camera (Samsung S9 plus) vita 3D master shade guide, tripod stand, grey card, DSLR camera(EOS Canon 1200D).

FIGURE: 2 – Armamentarium

METHODOLOGY- A commercial shade guide (3D master vita shade guide, germany) is employed in this study. The images of the individual shade tabs is captured using Samsung S9 plus smartphone camera and DSLR canon EOS 1200D. The Shade tab is placed over the grey card and the set up is placed in an area with good natural sunlight. The position is adjusted and the light temperature is measured which is around 4000 - 5000 K. The camera was mounted on a tripod and a fixed distance of 17cm was maintained between the shade tab and the camera. A total of 104 images are taken i.e, 2 photos for each of the 26 shade tabs were taken both in smartphone camera and DSLR camera. Best image was selected among the 2 depending on the clarity and sharpness. The settings of the cameras are described below :-

DSLR Settings

- Image was taken without flash
- Fixed shutter speed 1/125s
- Automated white balance
- Aperture F/22
- Type of metering - matrix
- ISO 100
- Flash mode - Off
- File type – RAW image

FIGURE: 3 – Set up of DSLR camera capturing the image of shade tab

SMARTPHONE SETTINGS

- Shutter speed – Automatic
- Automated white balance
- Aperture was set at automatic mode
- ISO – automatic
- Flash mode – Off
- File type – RAW and Jpeg image
- Type of metering – matrix, and the rest of the settings were in default/automatic mode.

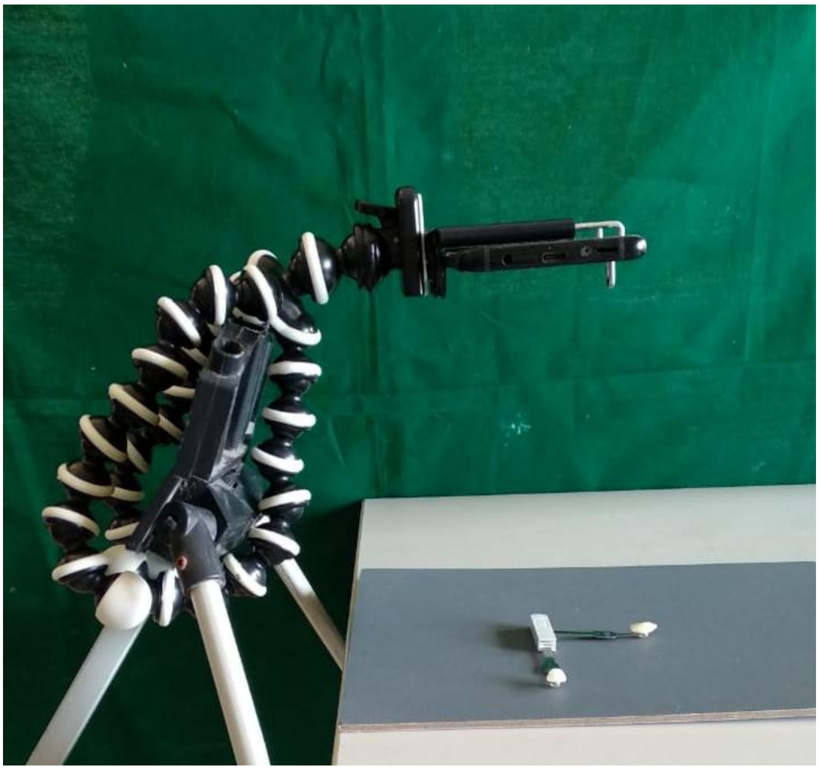


FIGURE: 4 - Set up smartphone camera capturing the image of shade tab

The images by smartphone were captured in raw and jpeg format and by digital camera was captured in raw format only. Raw file preserves most of the information from camera, such as sharpness, contrast, without processing and compressing. These usually have large file sizes and disables many camera effects. When it comes to image editing these are very versatile and will lose no details in further editing or compression. Jpeg file is a commonly used and popular image file format, which will be processed and compressed by the captured device according to the setting made by the user.

As per Bengel W M (2003) [38] protocol the following step-by-step procedure is to be followed :-

1. After starting the Photoshop program, open the Windows@ (Microsoft) Information menu; this will give you the color information of each single pixel
2. Use Ctrl + 0 to open the image to be analyzed
3. To eliminate an overall color cast, open the Levels dialogue by pressing CTRL + L (or Image, then Adjust, then Levels). Three eye-dropper tools will appear. Select the middle one and move it over the piece of gray card in the picture. Click again to eliminate the global color cast of the image. This can be controlled by checking the Information panel: The R, G, and B values, which would have been slightly different before, will now have the same value. The L a b values will have changed as well: a : and b will be set to 0; the L value will not have changed.

4. Change the color space from RGB to Lab. This has to be done for L a b values to be recorded using the histogram of Photoshop.
5. To obtain images with a comparable brightness, image brightness is compared with a medium value. The brightness of an image is expressed by the L value.
6. The selected tooth will be surrounded by a broken line on the monitor. This line indicates that all measurements refer only to the image content within the line.
7. Reflections on the tooth surface must be excluded.
8. L, a, and b values of the selected area are metered by clicking Image.

The L,a,b values of the raw images of smartphone were obtained using color lab and that of DSLR camera was obtained using adobe photoshop. The delta E Values of smartphone and DSLR in comparison with that of the manufacturers shade tab values were noted using color lab CIE2000 software. A scoring was given for the delta E values i.e. less than 2.5 is “not perceivable” and more than 2.5 is “perceivable” to human eye. This was done because the color difference between 2 objects (delta E) of < 2.5 is not discernible to human eye as suggested by Della Bona et al.[39]

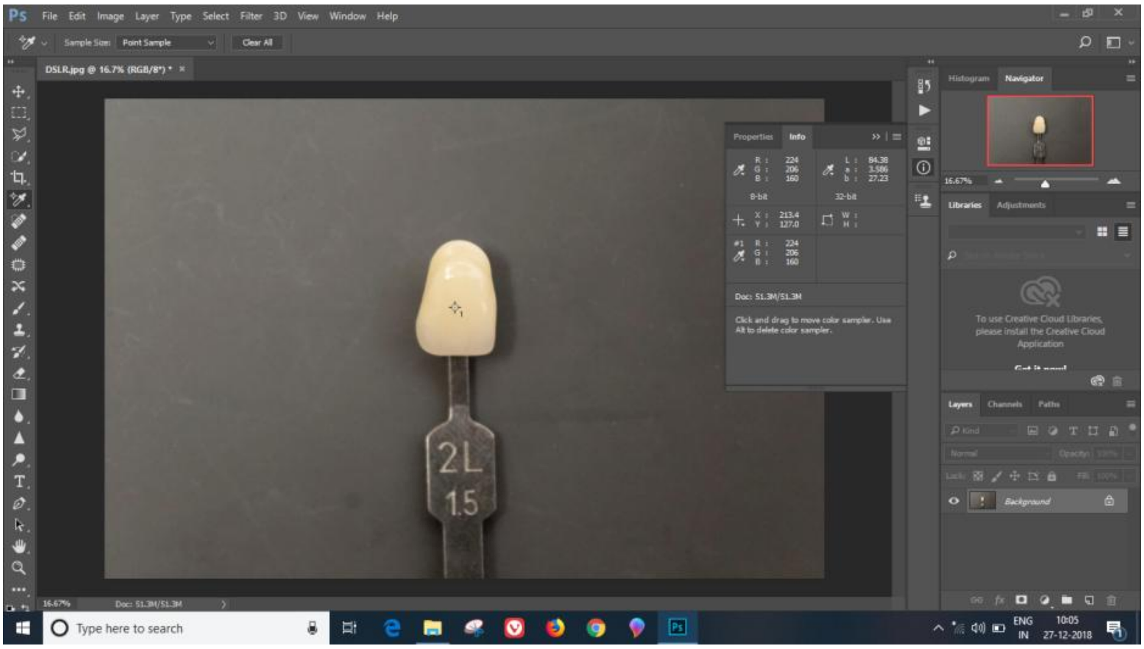


FIGURE: 5 – L a b value for DSLR image in Adobe Photoshop

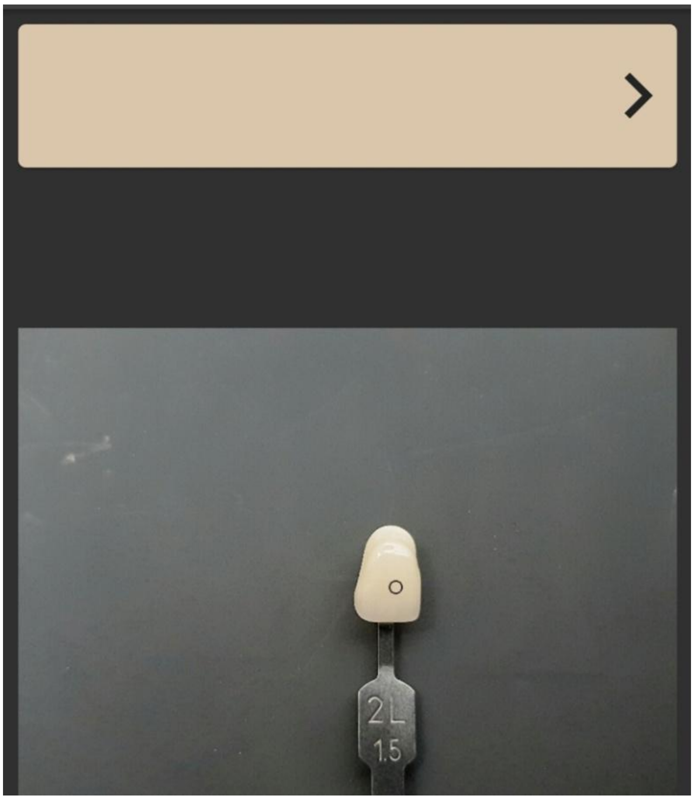


FIGURE: 6 - Smartphone image placed in Color Lab

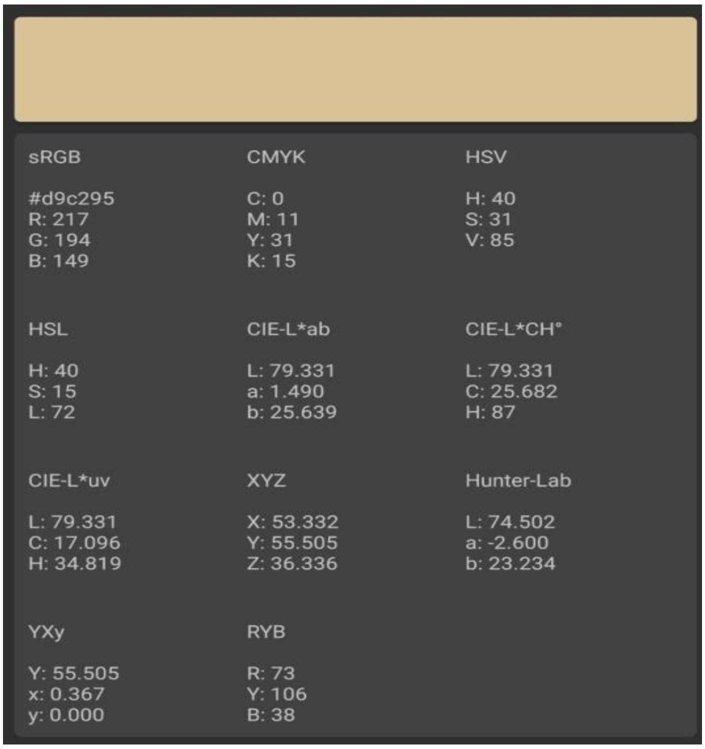


FIGURE: 7 – L a b values of smartphone image obtained using color Lab

In this study the L, a and b values were collected using DSLR camera and smartphone camera [Table 1]. For comparison of shades taken by the 2 variables the scoring values were taken into account.

TABLE: 1 – L, a, b and delta E Values of DSLR and smartphone images

SHADE 3D MASTER	MANUFACTURER Lab VALUES			DSLR				SMARTPHONE			
	L*	a *	b *	L 1	a 1	b 1	^E	L2	a 2	b 2	^E
1M1	83.1	-0.1	12.5	84.3	0.7	14.1	1.6	82	0.5	15.2	1.8
1M2	84	-0.2	18.8	84.2	-0.6	21.8	1.2	83.9	0.6	14.6	2.5
2L1.5	79	0	18.5	76.5	2.6	20	3.4	80	1.9	17.4	2.5
2L2.5	79.5	0.2	24.5	77.2	1.2	23.4	1.9	84.1	1.1	18.6	4.3
2M1	78	0.8	14	79	3	13	3.0	78.4	3.2	14.6	2.9
2M2	78.7	0.9	19.9	79	1.7	24.6	2.3	81.8	2.2	15.3	3.7
2M3	79.2	0.7	25.3	79.3	1.4	25.6	0.6	80.0	3.2	25.1	2.4
2R1.5	77.8	1.5	16.3	77.1	5.6	16.7	4.7	80.1	2.7	16.1	2.1
2R2.5	79.5	1.7	23.3	80.6	2.6	25.9	1.6	79.2	3	21.2	1.8
3L1.5	73.1	1.5	20.3	75.4	2.8	18	2.6	73.4	3.5	18.9	2.4
3L2.5	73.9	1.9	26.2	73.8	4.6	26	2.4	75.1	4.1	26.2	2.1

3M1	73.4	1.8	15.4	73.7	3.8	16.1	2.3	73	5.5	14.5	4.6
3M2	74.6	2	21.5	77.7	4.5	20.7	3.5	74.1	6.2	23.2	3.5
3M3	75	2.6	27.9	76.6	5.5	28.9	2.6	77.3	5.3	27.7	2.8
3R1.5	73.4	2.7	17.9	72.3	3.5	18.9	1.2	75.7	4.5	13.5	4.1
3R2.5	73.6	3.5	25.9	74.5	4.7	27.6	1.3	72.9	5.7	27.5	1.9
4L1.5	69.2	2.8	21.7	67.3	4.3	21.7	2.1	68.8	4.5	18.5	2.6
4L2.5	69.1	3.7	28.5	69.7	1.5	27.3	1.9	68.7	8.5	28.3	4.0
4M1	68.3	2.9	17.0	68.6	3.9	18.1	1.2	68.6	5.6	16.5	3.1
4M2	70.1	3.7	23.7	71.5	-0.7	29.2	4.9	71.7	8.8	23.8	4.8
4M3	69.5	4.8	30.7	70.01	3.9	30.4	0.8	64.6	8.9	21.9	3.3
4R1.5	69.6	4.3	20.8	68.4	4.2	23.9	1.8	69.4	5.7	17.6	2.6
4R2.5	69.2	5.1	26.3	68.8	5.4	29.9	1.6	68.2	7.9	27	2.4
5M1	64.4	4.2	19.4	70.1	3.7	18.5	4.5	64.8	7.0	20.6	3.3
5M2	65.1	5.7	26.3	67.6	5.3	26.6	2.0	68.9	7.9	26.9	3.4
5M3	65.9	7.0	33.4	67.4	4.6	25.8	3.6	73.3	7.1	33	5.75

Descriptive statistics is used to measure the variables. Below is the statistical analysis for the 26 shades for the difference between DSLR and smartphone photographs.

Table below shows the descriptive statistics of the change percent of smartphone and DSLR photographs.

TABLE: 2 DESCRIPTIVE STATISTICS OF DSLR CAMERA

	Minimum	Maximum	Mean	Std. Deviation
DSLR L1 change%	-8.85	3.16	-0.818	2.51
DSLR a1 change%	-500	800	-45.07	213.72
DSLR b1 change%	-23.6	22.8	-3.65	10.39
DSLR ^E	0.6	4.9	2.33	1.17

TABLE: 3 DESCRIPTIVE STATISTICS OF SMARTPHONE CAMERA

	Minimum	Maximum	Mean	Std. Deviation
SP L2 change%	-11.23	7.05	-1.16	3.23
SP a2 change%	-450	600	-77.19	202.03
SP b2 change%	-21.6	28.7	5.26	12.04
SP^E	1.80	5.75	3.10	1.01

INTERPRETATION- Table 2 & table 3 shows that the standard deviation of “L” and “b” is more in smartphone camera than DSLR, whereas standard deviation of “a” is more in DSLR than in smartphone. However the ^E values of both the groups does not differ much in standard deviation.

The change percentage of DSLR and Smartphone photographs for variables L, a and b from the manufacturing values are given below.

TABLE: 4

SHADE 3D MASTER	DSLR L_1 change %	DSLR a1 change %	DSLR b1 change %	SP L_2 change %	SP a2 change %	SP b2 change %
1M1	-1.44	800.0	-12.8	1.32	600.0	-21.6
1M2	-0.24	-200.0	-16.0	0.12	400.0	22.3
2L1.5	3.16	0.0	-8.1	-1.27	0.0	5.9
2L2.5	2.89	-500.0	4.5	-5.79	-450.0	24.1
2M1	-1.28	-275.0	7.1	-0.51	-300.0	-4.3
2M2	-0.38	-88.9	-23.6	-3.94	-144.4	23.1
2M3	-0.13	-100.0	-1.2	-1.01	-357.1	0.8
2R1.5	0.90	-273.3	-2.5	-2.96	-80.0	1.2
2R2.5	-1.38	-52.9	-11.2	0.38	-76.5	9.0
3L1.5	-3.15	-86.7	11.3	-0.41	-133.3	6.9
3L2.5	0.14	-142.1	0.8	-1.62	-115.8	0.0
3M1	-0.41	-111.1	-4.5	0.54	-205.6	5.8
3M2	-4.16	-125.0	3.7	0.67	-210.0	-7.9
3M3	-2.13	-111.5	-3.6	-3.07	-103.8	0.7
3R1.5	1.50	-29.6	-5.6	-3.13	-66.7	24.6
3R2.5	-1.22	-34.3	-6.6	0.95	-62.9	-6.2
4L1.5	2.75	-53.6	0.0	0.58	-60.7	14.7
4L2.5	-0.87	59.5	4.2	0.58	-129.7	0.7
4M1	-0.44	-34.5	-6.5	-0.44	-93.1	2.9
4M2	-2.00	118.9	-23.2	-2.28	-137.8	-0.4

4M3	-0.73	18.8	1.0	7.05	-85.4	28.7
4R1.5	1.72	2.3	-14.9	0.29	-32.6	15.4
4R2.5	0.58	-5.9	-13.7	1.45	-54.9	-2.7
5M1	-8.85	11.9	4.6	-0.62	-66.7	-6.2
5M2	-3.84	7.0	-1.1	-5.84	-38.6	-2.3
5M3	-2.28	34.3	22.8	-11.23	-1.4	1.2

INTERPRETATION- Maximum change percent of DSLR and smartphone camera has been shown for variable “a”. Change percent is more for “a” in lighter shades compared to darker shades. As per table 4, least change percent is shown in the variable “L” of DSLR camera photographs.

The last and most key objective of the study is to differentiate between the 2 variables i.e. between the Smartphone and DSLR shade detection using Delta E values.

So, to compare group 1with group 2 interventions, **Wilcoxon signed rank test** can be used when assumptions of paired t-test are not met.

Table: 5

Descriptive Statistics					
	N	Mean	Std. Deviation	Minimum	Maximum
DSLR ^E	26	2.331	1.1712	.6	4.9
SP ^E	26	3.1019	1.01474	1.80	5.75

INTERPRETATION- The mean of DSLR ^E and smartphone ^E is 2.33 and 3.10 respectively. The maximum standard deviation of DSLR is 4.9 and minimum is 0.6 and for smartphone maximum is 5.75 and minimum is 1.80. The standard deviation of both DSLR and smartphone delta E does not vary much.

Table:6

Ranks				
		N	Mean Rank	Sum of Ranks
SP ^E – DSLR ^E	Negative Ranks	7[a]	9.07	63.50
	Positive Ranks	18[b]	14.53	261.50
	Ties	1[c]		
	Total	26		

a. SP ^E < DSLR ^E

b. SP ^E > DSLR ^E

c. SP ^E = DSLR ^E

Table: 7

Test Statistics[a]	
	SP ^E - DSLR ^E
Z	-2.665[b]
Asymp. Sig. (2-tailed)	.008
a. Wilcoxon Signed Ranks Test	
b. Based on negative ranks.	

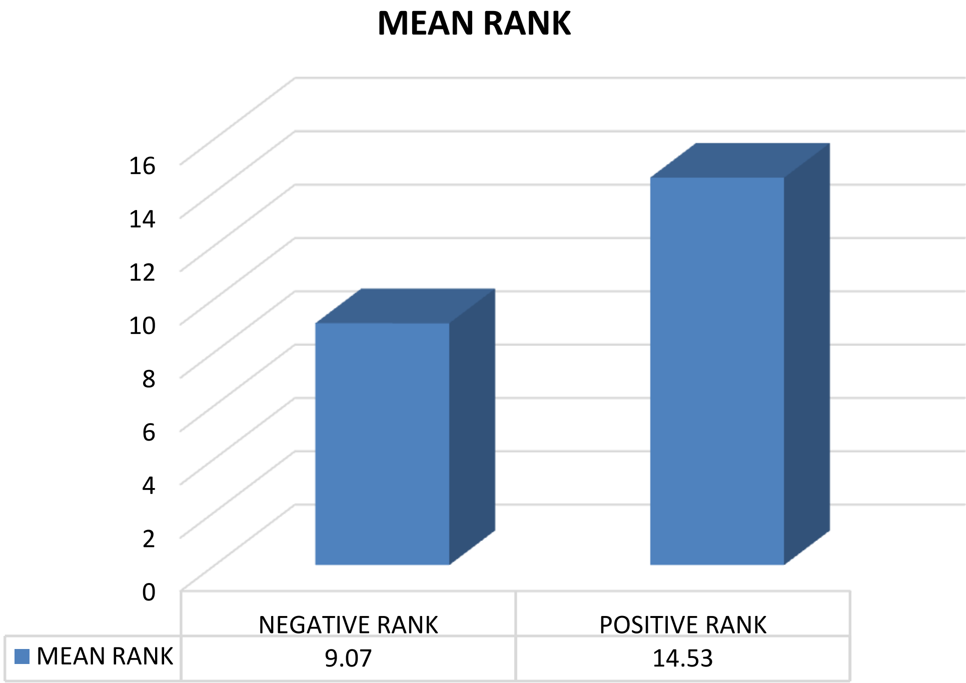
Interpretation: Wilcoxon signed rank test is performed between DSLR and Smartphone photographs to determine if there is significant difference for deviation (Delta E) values.

The calculated test statistic value in table (Table: 5) is lesser than the critical value(p value) i.e. there is **significant difference** between the amount of deviation of L,a and b values in DSLR and Smartphone photographs.

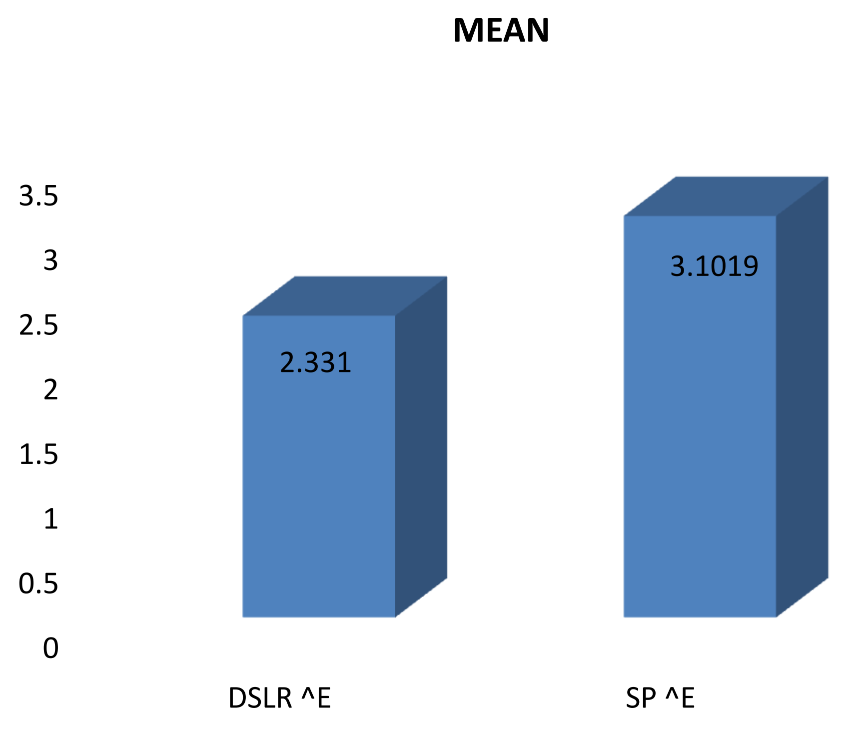
The value of p value is **lesser than 0.05(0.008**) [Table7] which aids rejection of null hypothesis, i.e. there is difference between the amount of deviation of L, a and b values in DSLR and Smartphone photographs. The sum of ranks shown in Table 6 shows that positive sum of ranks has a higher value which is Smartphone Delta E values are higher than DSLR delta E values.

GRAPHS:

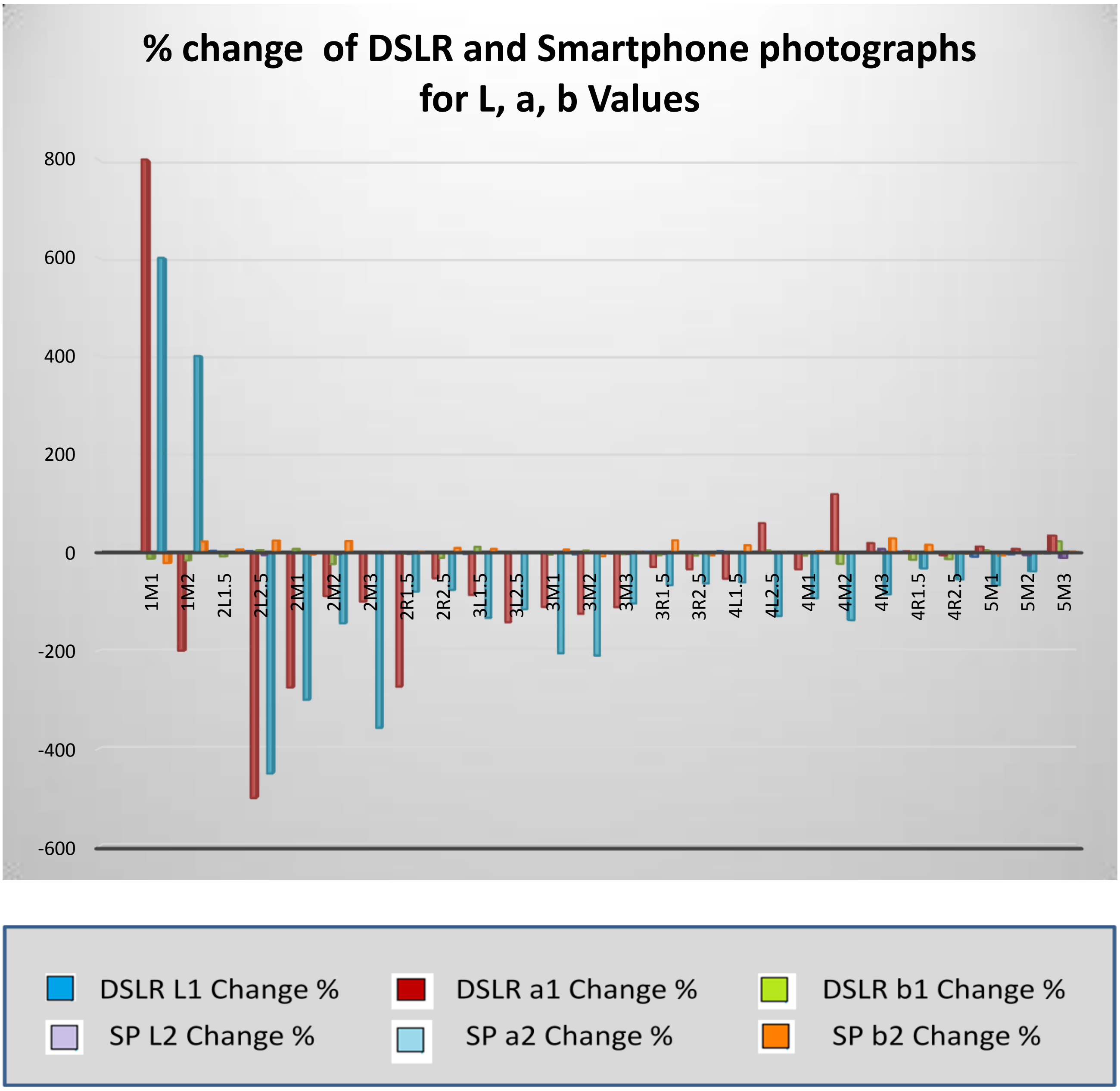
MEAN RANKS OF SP ^E - DSLR^E



MEAN OF SP^E AND DSLR^E



The change percentage of DSLR and Smartphone photographs for variables L, a and b from the manufacturing values



The form, function, and esthetics in a restoration is of prime concern. Esthetically pleasing restoration depends on proper shade matching. Perfection in shade selection can only be achieved when the prosthesis is an accurate replica of the adjacent natural tooth. Shade selection varies depending on the clinician’s color perception and experience, lighting conditions, tooth background, and the shade guide used. Communication with a dental laboratory is another problem as the technician does not usually see the patient and has to work on dentist’s written instructions.

To overcome the discrepancies of shade selection, digital cameras were introduced in dentistry which enabled clinicians to perform an objective analysis. A digital photograph helps to exactly replicate the color of the restoration due to its high image quality. Wolfgang M et al in 2003 stated that a photographic procedure using digital cameras are proposed that is relatively simple and sufficiently precise to allow the assessment of the therapeutic outcome of tooth-bleaching procedures.[40]

As there is increase in prevalence of smartphones with high resolution cameras, the photographs captured by this can be taken as color references in dental shade matching. Because color communication requires photographs with reference shade tabs [41], smartphones can increase the ease of wireless communication between dentists and the laboratory technicians who fabricate dental prostheses.[35]

Wen- kong tam in 2016 [35] conducted a study on dental shade matching by using digital images that may be feasible when suitable color features are properly manipulated. They proposed using support vector machines (SVM), which are outstanding classifiers, in shade classification. They concluded that this study provides a feasible technique for dental shade classification that uses the camera of a mobile device. The findings reveal that the proposed SVM classification might outperform the shade-matching results of previous studies that have performed similarity measurements of the levels or used an s*, a*, b* feature set.

Based on Pubmed and Google search this is the first study to compare the perceivable color difference of vita 3D master shade guide tabs using smartphone camera and digital camera. Some earlier studies compared several digital cameras available at a point in time among each other in order to choose the best one for telemedicine purposes [42]. Kodak V1s233 was chosen as providing the best solution. The Fuji F40 would serve well if a docking station is not needed. The Casio EX-Z1200 is a good choice if the user can be trained to utilize the macro setting properly.[43]

Our study describes the comparison of L,a, and b values of DSLR images and smartphone images with that of the manufacturers specifications. The images were taken under controlled environmental factors with 18% grey card kept behind the shade tab as close as possible, which is a neutral target as its red, blue and green values are equal. Since the gray card had definite values, the software also interprets it as gray, thus eliminating the color cast of the whole picture[44]. The images were in Raw format as this is an uncompressed file type with the most color information and is also easily fixable if the camera settings were set wrong initially. Edward A. Et al [45] stated that with an accurately and consistently exposed image taken in RAW format, and with the use of WhiBal Gray card and correctly positioned shade tabs, general practitioners can take a shade analysis image that can be used to extract shade information in photoshop using the Lab and HSB color models. In the author’s experience this has been directly useful in choosing the correct shades of ceramics for indirect restorations.

The data and analysis of the study support rejecting the null hypothesis. In this study it was determined that the subject effects were statistically significant.

The Vitapan 3D-Master shade-matching system is used in this study as it is extensively used in dental clinics and has been shown to enable shade matching. The use of the Vita 3D Master shade guide alone is just as effective as using all 3 shade guides combined (VITA Lumin, Chromascope & vita 3D Master), which is less clinically practical. Since the L,a and b values would vary for each shade tab, the values given by spectroradiometer was taken as a control group.

Delta E is the distance between 2 colors and is used to ensure the colour being displayed is reproduced with colour hue that matches so closely to the colour input that the human eye can't perceive the difference. The higher the value of Delta E (ΔE), shows that further away the colour is from the true hue, using CIELAB. Delta E of zero cannot be detected using the human eye, thus is the perfect color value. Few studies state the minimal detectable difference is between 1-2.5 Delta E. A Delta E between 3 and 6 is usually considered an acceptable number in commercial reproduction, but the colour difference may be perceived by printing and graphic professionals [46]. There are few other studies that say less than or equal to 1 is not perceptible by human eye, 1-2 will be perceptible through close observation and 2-10 perceptible at a glance.

In Table 4 it is shown that the change percentage of L (luminosity of color) is less in DSLR when compared to smartphone. Out of the 26 shade tabs higher DSLR change percent of L is visible in 5 shades i.e 2L1.5, 3L1.5, 3M2, 5M1 and 5M2 shades. An acceptable change percent of "a" in DSLR is in shade tab 4R1.5 and in smartphone 5M3. Wilcoxon signed rank test is performed between DSLR and

Smartphone photographs to determine if there is significant difference for deviation (Delta E) values.

The calculated test statistic value in table (Table: 5) is lesser than the critical value (p value) i.e. there is significant difference between the amount of deviation of L,a and b values in DSLR and Smartphone photographs.

Table 1 shows the delta E values of DSLR and manufacturers and smartphone and manufacturers. On taking delta E acceptable value as less than or equal to 2.5, shades 2L1.5, 2M1, 3L1.5, 2R1.5, 3M2, 3M3, 4M2, 5M1 and 5M3 of DSLR camera showed perceivable color difference. The rest of the shade tab have values that have no or barely perceivable color difference. Similarly smartphone delta E shows no color difference in shade tabs 2L2.5, 2M2, 3M1, 3M2, 3M3, 3R1.5, 4L1.5, 4L2.5, 4M1, 4M2, 4R1.5, 5M1, 5M2 and 5M3. Thus on analyzing table 6 it can be stated that 66% accuracy was obtained for DSLR camera and 47% accuracy for smartphone cameras. On the other hand if delta E value is taken as less than or equal to 2, shades 2L1.5, 2M1, 2M2, 2R1.5, 3L1.5, 3L2.5, 3M1, 3M2, 3M3, 4L1.5, 4M2, 5M1 AND 5M3 of DSLR camera and shades 1M2, 2L1.5, 2L2.5, 2M1, 2M2, 2M3, 2R1.5, 3L1.5, 3L2.5, 3M1, 3M2, 3M3, 3R1.5, 4L1.5, 4L2.5, 4M1, 4M2, 4R1.5, 4R2.5, 5M1, 5M2 and 5M3 of smartphone camera shows color difference perceptible at a glance. Thus, 50% accuracy is obtained for DSLR camera and only 16% accuracy is obtained for smartphone camera.

The results of the study showed that the L,a and b values of smartphone camera photographs showed more deviation when compared to DSLR camera photographs.

Dhruv Anand[32] conducted a study to ascertain if digitally acquired images with an SLR camera can be used as an alternative to the VITA easyshade spectrophotometer for obtaining the shade of the teeth. It was observed that the L and b values obtained by both the methods were highly significant, whereas ‘a’ value was not significant. Thus it was concluded that SLR camera with Adobe photoshop CS5.1 as an adjunct can be used as an alternative to spectrophotometer for obtaining ‘l’ and ‘b’ values accurately.

In our study the maximum change percent of DSLR and smartphone camera has been shown for variable “a”. Change percent is more for “a” in lighter shades compared to darker shades. As per table 4 least change percent is shown in the variable “L” of DSLR camera photographs.

Stephen J.Chu in 2010[47] inferred in his review that Color communication is best performed using reference photography with reference shade tabs from current shade guide systems obtained using digital camera.

A study conducted by Constance Boissin et al[48] series of nonclinical objects were photographed by a professional photographer using three smartphones i.e. iPhone_ 4, Samsung Galaxy S2, and BlackBerry_ 9800 and a digital camera. A Web survey was conducted wherein convenience sample of 60 laypeople ‘‘blind’’ to the types of camera assessed the quality of the photographs, individually and best overall. On statistical analysis there were wide variations between and within categories in the quality assessments for all four cameras. The iPhone showed the highest proportion of images individually evaluated as good, and it also ranked best for more objects compared with other cameras, including the digital one. The ratings of Samsung or BlackBerry smartphones did not significantly differ from those of the digital camera. It was concluded that where one smartphone camera ranked best more often, all three smartphones obtained results at least as good as those of the digital camera. Smartphone cameras can be a substitute for digital cameras for the purposes of medical teleconsultation.

In our study we decided to use Samsung galaxy S9 Plus which has a rear dual lens camera, also known as stereo camera. The dual lens camera helps to capture a vivid and detailed picture. As per the DxOMARK scoring, Samsung galaxy S9 Plus takes the number one spot in mobile ranking.

Fabiana Takatsui et al in 2012[27] conducted a study to analyze the color alterations performed by the CIE Lab system in the digital imaging of shade guide tabs, which were obtained photographically according to the automatic and manual modes. Four Vita Lumin Vaccum shade guide tabs were used i.e. A3.5, B1, B3 and C4. An EOS Canon digital camera was used to record the digital images of the shade tabs, and these images were processed using Adobe Photoshop software. A total of 80 observations were obtained, leading to color values of L, a and b. The color difference (ΔE) between the modes were calculated and classified as either clinically acceptable or unacceptable. The results indicated that there was an agreement between the two observers in obtaining the L, a and b values related to all guides. However, B1, B3, and C4 shade tabs had ΔE values which was classified as clinically acceptable ($\Delta E = 0.44$, $\Delta E = 2.04$ and $\Delta E = 2.69$ respectively). The A3.5 shade tab had a ΔE value classified as clinically unacceptable ($\Delta E = 4.17$), as it had presented higher values for luminosity in the automatic mode ($L = 54.0$) than in the manual mode ($L = 50.6$). It was concluded that the B1, B3 and C4 shade tabs can be used at any of the modes in digital camera (manual/automatic), which was a different finding from that observed for A3.5 shade tab.

In our study, table 1 shows that the delta E values of whiter shades like 1M1, 1M2, 2L2.5, 2M3, 2R2.5 shows less distance between the 2 colors than the yellow shades like 3R1.5, 4M2, 5M1, 5M2 and 5M3.

In this experimental set up the smartphone was kept in auto mode while DSLR was in manual mode. The variation within each camera can contribute to color accuracy. The variations include cameras sensor, lenses, white balance, software used to convert raw format file etc. The image samples were captured on a bright daylight with a 4000-5000 K color temperature which might have produced variations in illumination. Although the smartphone camera automatically adjusted the settings according to the brightness of the environment, the camera sensor might have experienced varying light exposure in different shots. Such unexpected variation in the light projecting onto the sensor might have affected the shade color features of individual shots.

Therefore further investigations are required concerning the experimental set up of the smartphone galaxy S9 Plus camera.

The purpose of the study is to assess the effectiveness of smartphone camera in shade selection and to compare its efficacy with that of the DSLR camera images. Thus, a vita 3D Master shade guide was used to capture the shade tab images using DSLR camera and smartphone camera. The statistical results showed that the “L” and “b” values of both DSLR and smartphone camera is more compatible with the values given by the manufacturers of vita 3D Master shade tabs and “a” had higher variations. Moreover Images taken in DSLR camera provided a better color agreement when compared to smartphone.

Understanding the different variables of color in all shade tabs, vita 3D master shade guide gives a logical selection of properties of color. However further investigations can be carried out with different shade guides.

Within the limitations of the study it can be concluded that on assuming delta E Values as less than or equal to 2.5, 73% accuracy was obtained for DSLR shade tabs whereas only 50% accuracy was obtained for the smartphone which is best available in the market now. Thus color measurements of vita 3D master shade guide obtained with DSLR camera was in accordance with that of the manufacturer’s value.

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Omsakthi

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DENTAL COLLEGE & HOSPITAL
Recognised by Dental Council of India
Affiliated to The Tamilnadu Dr.M.G.R Medical University
A Unit of Adhiparasakthi Charitable, Medical, Educational & Cultural Trust

This Ethical Committee has undergone the Research Protocol submitted by Dr. Vidhu Antony, Post Graduate Student, Department of Prosthodontics, Crowns & Bridges, under the title "Comparison of Shade Selection by Smartphone Camera and DSLR Camera using Vita 3D Master shade guide-An Invitro Study" Ref no: 2016-MDS-Br I-ASR-02/APDCH under the guidance of Dr.N.Venkatesan for consideration of approval to proceed with the study.

This Committee has discussed about the Material being involved with the study, the Qualification of the investigator, the present norms and recommendations from the Clinical Research Scientific body and comes to a conclusion that this Research protocol fulfils the Specific requirements and the Committee authorizes the proposal.

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URKUND

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Analysed Document: FINAL WRITE UP.docx (D46319757)
Submitted: 12/30/2018 3:50:00 PM
Submitted By: drvidhuantony@gmail.com
Significance: 4 %

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